CHAPTER 8

POTTERY, TRANSPORT, TEXTILE AND OTHER TECHNOLOGIES

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1. PRELIMINARY REMARKS

We have so far argued that notwithstanding the serious difficulties caused by the lack of any direct document testifying to mathematics and astronomy in the ancient Indus Civilization, there are circumstantial evidences wanting us to presume the making of these as "conscious" sciences during the period of our First Urbanization. It remains for us to discuss the question of the possibility of the emergence of conscious science in other forms—specially what we call nature sciences these days like chemistry, biology, physics, etc.—during the same period.

Our starting point, however, is formed of the archaeological data concerning the main technologies of the Harappan culture, because we began with the proposition that conscious science—whatever form it may eventually acquire—is necessarily rooted in technique. Without an overview of the more prominent technologies of the Harappan period, therefore, we cannot proceed to the question of the possibility of other conscious sciences in the Harappan civilization. The present chapter as well as the one following it are intended to give such an overview. In the first of these two chapters, a sketch of some prominent technologies as pottery, transport, textile, etc. are given, while that of metal technology in the second. The reason for having a separate and somewhat detailed discussion on metal technology is that among the various techniques it has the greatest potentials of moving towards what is sometimes described as the approximation to international science.

I am indebted to my young colleagues Santanu Maity and his wife Sujata Maity—both of whom are working archaeologists—for sketching out the present chapter. For the next one I am most grateful to D.P. Agrawal—one of our leading archaeological scientists—for the permission of using his article published sometimes back in the *Indian Journal of the History of Science* : D.C.

2. POTTERY AND CERAMIC

In archaeology pottery is regarded as the index to culture. To an archaeologist pottery assumes the importance of the alphabet. Though profusely found in archaeological excavations and explorations in the cultural frontiers of ancient India most of these are not tested in the laboratory. Generally archaeologists are inclined to the typological study of the sherds and their probable correlation with others. In most cases technological analysis is not properly done. But the technological study in details—such as the composition of clay, tempering agents, nature and components of the slips or glaze, nature of firing, porosity test and different chemical analyses—may throw light on the technological advancement of a culture. Not only that, the scientific study of pottery "throws light on almost every aspect of the past—social, cultural, religious, economic, political and what not."[1] Though the importance of pottery for archaeological reconstruction of past cultures is immense, yet "Archaeologists, in India no less than other parts of the world, have often been imprecise in the terms they employ in describing pottery, and no single system of description has so far been accepted."[2]

Each and every object, found either in excavations or in explorations has its own history of technology. But their finders are not always in a position to determine their technological "make up", either due to ignorance or sloth. But so far as the understanding of the Harappan Ceramic technology is concerned, we are indebted mainly to E.J.H. Mackay, who has discussed it elaborately, both in Marshall's book and his own.[3] Not only pottery; Mackay has also discussed the techniques of manufacturing other objects, which are on the whole accepted by the scholars of the succeeding period. I have before me a book with the title : *A study of Harappan Pottery* by O. Manchanda.[4] In this book what is discussed about 'General Characteristics' of Harappan pottery—seems to be an echo of Mackay. Even what Sankalia discussed in his *Some Aspects of Prehistoric Technology in India* is no exception to this. Mackay is there-

1. B. B. Lal in PAI 3.
2. B & R Allchin BIC 287.
3. J. Marshall MIC Vol. I; Mackay FEM.
4. O. Manchanda SHP.

fore the pioneer in scientific approach to the subject. In our own discussion we have generally tried to follow him.

Since the twenties of our century innumerable Harappan sites have come to light in a widely distributed area, thanks to the field-work of the archaeologists of many countries. Recently the homogeneity of the Harappan culture in various aspects has been challenged by some scholars on the basis of fresh archaeological data.[5] In fact, regional diversity of any culture is an accepted phenomenon in the field of archaeology. The Harappan culture is no exception to this. But the pottery technique of the Early, Mature and Late Harappan phases was basically the same. It is from this technique and its products that the dynamism of a culture either in its mature or decadent forms can be easily ascertained though along with its regional diversities. While discussing pottery of the Harappan period, the Allchins in their earlier work observed :

> The extra-ordinary self assurance of the pottery of the Harappan period calls for comparison with the crafts and arts of the Roman empire or of Victorian Britain. There is extreme standardization, and technical excellence goes hand in hand.... Even after allowing for the increasing 'Indian-ness' of the craft, its roots in the west, in Baluchistan and Iran, are undeniable.[6]

But in their subsequent work, they seem to put greater emphasis on the more "Indianness" of the technique : "Mature Harappan pottery represents a blend of the ceramic traditions of Baluchistan on the one hand, and those of India east of the Indus (as exemplified in Fabric A at Kalibangan) on the other.. it developed its own somewhat stolid character...competent and self-assured."[7]

.It reminds us of Marshall who said[8] :

> The very multiplicity and variety of its shapes—most of them peculiar to the Indus Valley and quite distinct from those of Persia and Mesopotamia—are evidence enough that the craft of the potter had been practised there from time immemorial.

In the same volume E.J.H. Mackay[9] observed :

5. B. K. Thapar in B. B. Lal (ed.) FIC 14-15.
6. B & R Allchin BIC 288.
7. B & R Allchin RCIP 197.
8. J. Marshall MIC I, I. 28
9. Mackay in Marshall's MIC, I, 287.

Little of the pottery from Mohenjodaro resembles in shape that hitherto found in Mosopotamia and Elam. The wares even of adjacent countries are seldom much alike in form; each race evolves such shapes as are suitable and uses them with but slight modifications over long periods. It will be seen that most of the pottery forms are far removed from being primitive, showing that the potter's craft was well advanced.

On the basis of the above observations, we are inclined to suggest that for the history of origin and technique of Harappan pottery, we need not look abroad. It had its own technological development in Indian subcontinent, neither in Egypt and Iran, nor for that matter in the "fertile crescent".

The Harappan pottery is generally called as the Black on Red Ware, because this constitutes the majority of the entire assemblage. But excavations and explorations at major Harppan sites have yielded many other varieties, such as Red Ware, Buff Ware, Gray Ware and Black and Red Ware etc. Of course, such categorization is based on broad divisions and is not strictly applicable. These potteries are either plain or of the painted varieties; except at Kalibangan nowhere the percentage of painted and unpainted varieties has been absolutely detected. The potteries are of two fabrics—fine and coarse—and the section varies from thin to thick according to their shapes. It has already been mentioned that the shapes of the Harappan pottery are quite different from those of Iran, Mesopotamia and Elam. Nigam[10] likes to classify the shapes into the following groups:

(A) The shapes which are met only in the Harappan civilization. These include goblets, beakers, perforated jars, certain types of jars, and vases etc. (B) In this group can be placed such shapes which occur in the pre-Harappan cultures and continue in the Post-Harappan period in association with other cultures. Here are such common shapes viz., dish-on-stand, cup-on-stand, bowls, dishes, basins, caskets, vases, jars, lids and ring-stands etc. (C) Zoomorphic containers, and (D) The Black and Red Ware.

Such considerable varieties of shape would not have been possible if the potter's craft was less advanced. Technological inheritance for generations was the prime force behind this perfection.

10. J. S. Nigam, in EIP 136.

The quality of pottery depends to a great extent on the selection and preparation of clay. The textural integrity and evenness of the surface of the pottery is obtained by means of selecting fine clay devoid of rough and coarser elements. The potters of the Harappan period had the opportunity of utilising and employing local alluvial clay for pot making. In fact, this was easily available from the bed of the rivers and was not much laborious for levigation. Well levigated clay was essential for pottery. On the basis of the practical study of the nature of the clay, the Harappan potters would have selected the natural alluvial clay. Not only that; they might have their efficient process of levigation of clay for the production of the pottery in a mass scale, though the archaeological evidences for this are still lacking. Evidences for the preparation of clay, one of the most vital aspect of potting technique, are also still lacking. Yet most probably in ancient Sind the process was the same as it is today. The potters were content merely to beat the clay dry, and to strain it through the canesieve. But another easy method of collecting dry clay, picking up and throwing out the rough and coarser agents and thoroughly kneading it with the required water quantity might have also been followed by them.

On analysis it is found that Harappan Wares contain sands and lime, either singly or both; these were mixed with the clay of both painted and unpainted pottery. Sand is regarded by the potters as the 'bone' of pottery. Mica has also been traced as a tempering agent or degraissant along with sand or lime, and so far mica is concerned the mixing was probably not deliberate, because mica is naturally found in the sand on the banks of the Indus. Both sand and mica are essential for the smooth handling of clay on the wheel and they also save the pottery from cracking while being dried in the sun. Sometimes smaller jars were made of a special paste, devoid of sand and lime. However, when burnt the clay generally turned pink or light red and this was due to the presence of iron compounds in the clay. For Gray Wares, according to Mackay, a paste of slate colour—in some cases approaching black—was employed. In his view:[11]

11. Mackay FEM 174-75.

> Clay of this kind apparently required no tempering, and only in exceptional cases was any other substance mixed with it for this purpose. Whether the colour of the pottery made from it was natural or was darkened by the admixture of some carbonaceous material with the clay has yet to be determined. I am inclined to think that as this pottery varies considerably in tint something was added in varying proportions with the purpose of darkening it.

Hamid suggests that this was due to the presence of ferrous iron in the clay.[12]

Potteries are shaped either by hand or on wheel or by moulding. A few handmade sherds are found in the entire assemblage of Harappan pottery so far and the hand-modelling was also rather crude, which could be the work of children. No moulded variety has yet been reported by the excavators. In fact, almost all the pottery assemblage of Mohenjo-daro, Harappa and other sites are wheelmade; but scholars are not unanimous about the wheel on which these were shaped, because the material representation of an actual potter's wheel has not yet been found. But both Mackay and the Allchins, studying the evenness and striation marks on the pottery have suggested the use of footwheel, which is still found at Beluchinstan and Sind. Mackay likes to give credit to the Harappan (and not to the Aryans) for introducing footwheel in the region. The Allchins[13] observe :

> The foot-wheel is still in use in Sind and parts of the Punjab, Saurashtra, and the North-west Frontier province, in contrast to the Indian spun-wheel found east of the Indus, and may be taken with some degree of certanity to be a legacy of this period. The modern foot-wheel closely resembles those which are found right across Iran and into Mesopotamia, both today and probably in ancient times.

Though the use of the foot-wheel has been suggested by Mackay and the Allchins, the possibility of using hand-wheels for potting cannot be altogether ruled out, because hand-wheels have also produced wares not inferior to the Harappan pottery. Without the actual evidence of the wheel used in that period, we may suggest the simultaneous use of both types of wheel. The advantages of a particular type over the other cannot always completely oust the less advantageous one ; it is rather likely to be dominant.

12. Marshall, MIC, I, 311 note-2.
13. B & R Allchin RCIP 199.

The majority of the vessels of Harappan period have a flat base, yet round-bottomed or pointed based potteries are not altogether rare. The flat base of a pot was more convenient for flat brick-paved floors. These flat bases have groovings which indicate that the pots were removed from the wheel by a string or grass in slow motion. The string was held either between two hands of the potter or one end of the string was tied to the little finger of the potter and the other stuck again on the base of the pot which was to be removed from the wheel, so that while the wheel was in motion the jar was automatically cut off. The bases of Harappan potteries are not well finished in comparison to the upper portion. Trimming on the lower portion is a common feature of the Harappan pottery. It was done in vertical direction by a knife or some similar instrument.

Sometimes the jars having angular shoulders were at first made in two pieces which were fitted together when wet and again they were put on the wheel for the final touch. But these fitting points are not easily detectable due to their obliteration by trimmings both inside and outside. Offering stands other than the jars were also made in two pieces—the first part is that of base and stem and the second part is the pan. It is likely that after the modelling of the pots they were dried in a steady temperature, and to reduce porosity burnishing was done by mechanical friction on the surface in a 'leather-hard' stage.

The natural surface of the pottery was hidden, because slip was used on its surface before firing, which added to the pot a polish, lustre and bright hue. Not only that. It was also used as a preventive against the porosity of the pottery with the aid of a mop. Sometimes slips were applied to the pot more than once according to necessity. The slips were of various colours, viz., cream, white, black, chocolate, purple, pink etc. Slips of red oxide for better class pottery were used. Black slip was probably obtained by using lamp black or powdered charcoal added to the levigated clay. The juice of Tuthi (*abutilon Indicum*) was probably applied to give a black gloss on the surface.

For decorative devices some other treatments were done before firing: cording, incising, scoring, perforating or by employing impressions on the pottery. For cording, a cord

was wound around a vessel when it was on the wheel, either in slow motion or in a stationery state. Incising was generally confined to the bottom of the pans, and it was probably done by a pointed tool or metal comb. Scoring was executed generally on the upper part of the pottery with a very sharp tool, most probably a metal comb. Many perforated cylindrical vessels and potsherds are found at several Harappan sites, the purpose of which is still undetermined. Mackay observes[14]:

> The pattern was scratched on the unbaked clay of this perforated ware to guide the work of the cutter; some of these marks remain, though they should all have been removed in the process of cutting the incisions.

Impressions were executed probably by a wooden stamp before the baking of the pot. But another type of incising needs to be mentioned. These are the graffiti marks on the pottery. This was generally done with the aid of a pointed tool after the baking. One such sherd bears the representation of a boat. Such graffiti marks have also been found on the gray sherds.

Paintings were drawn on the potteries before or after baking. Paintings which were executed on the pottery before baking were composed of inorganic substances and due to chemical changes in firing a considerable colour range was achieved. It is observed in the *Early Indus Civilisation* that "The slip used for a great part of the painted ware is red ochre,... After a jar had been shaped on the wheel, the ochre was painted thickly over it, ... The designs....were painted on this red surface with a brush before firing, the material used being a thick, black, or purplish-black, paint made from manganiferous haematite".[15]

Baking of pottery is one of the most vital stages of that craft—the stage in which the Indus potters showed their excellent skill and capacity. Mackay[16] observes :

> The pottery of Mohenjo-daro was well baked. The resulting fabric was hard enough to stand a considerable amount of knocking about, and its uniformity of colour shows that the potter had considerable

14. Mackay FEM 181.
15. Mackay EIC 109.
16. Mackay FEM 176.

control over the heat of his furnace........ We have found comparatively few over-baked vessels that had been put into use; nor do I remember a jar or potsherd that could be said to be underfired, though some mistakes must have been inevitable.

Due to firing—either in kilns or in open fire—some chemical changes occurred in the clay and these changes depended mostly on the composition of the clay, the temperature of firing etc. As Mackay[17] says:

The firing of a jar appreciably altered its colour, changing a light grey clay to a pinkish-red shade owing to the checimal action of the small amout of iron in it. Those very few specimens which are definitely over-fired have a distinctly greenish hue, which is due to the presence of a complex ferrous compound in whose formation lime plays an important part.

In Marshall's *Mohenjo-daro and Indus Civilization* vol. 1., Mackay, due to the lack of evidence reported that probably the potteries were burnt in open fires. But in his own later work he has changed his opinion considerably due to the findings of the potter's kilns in subsequent exacavations. Thus, he observes[18]:

In the more recent excavations, however, we have found quite a number of kilns, which judging from the masses of potsherds around them were exclusively used for the baking of pottery. The remains of two such kilns were unearthed.

Following Mackay, Hegde has discussed the kilns in his article *Ancient Indian Pottery-Kilns*. The description of the kilns, in Mackay's[19] words, is:

The main features.....are a pit for the wood or reed fuel and a domed compartment above to hold the vessels to be baked, communication between the two being effected by round holes in the floor of the upper chamber.

Certainly kiln baking had some advances over the open firing method, yet Hegde is probably right when he says[20],

It is doubtful if much of the Harappan pottery was baked in kilns.... The rarity of ancient Indian pottery-kilns in the archaeo-

17. *Ibid.*
18. *Ibid* 177.
19. *Ibid.*
20. K. T. M. Hegde "Ancient Indian Pottery-Kilns" in *Puratattva* No. 9, 1977-78, 110.

logical record suggests that more than 99 percent of the ancient Indian pottery was baked in open fires. But unfortunately for the archaeologists, this baking device does not leave behind tangible evidence.

Actual observations have shown that potteries produced by open-fire is not inferior to the kiln-burnt ones. The large scale demand of the Harappan population inclusive of trade certainly required a mass production of pottery which could not be fired only in the constructed furnaces or kilns. It is probable that some special class of pottery for which special care in baking was needed was burnt in the kilns, while the others were prepared by open fire method.

After baking, a pot is ready to serve its purpose. But sometimes paintings are executed on it for decorative purposes. Harappan potteries are inclusive of painted varieties. These are either monochrome or polychrome. It has already been suggested that the clay and other components of plain and painted wares were almost the same. Sometimes a raised effect on the surface was offered by means of applying paints on the already polished slip by hair brushes of varying fineness or by a reed pen. For polychrome wares red ochre and a green pigment "terre verte" were used; but in polychrome wares painting was generally executed after baking. Innumerable designs were painted: intersecting circles, triangles, squares, lozenges, floral and animal designs etc. It is most probable that some of the designs not only required knowledge of geometry but also some instruments such as the compass and scale. Not only that; some anatomical data appear to be embodied in depicting animals and human motifs.

Lastly, we may have some words on the so-called glazed wares or Reserved Slip Wares and Black and Red Wares. Practically speaking, there is little difference between glazed and Reserved Slip Wares. Their process of manufacturing is almost identical. F.R. Allchin has expressed his doubt whether these were truly glazed or had only a surface gloss due to polish.[21] Mackay himself was doubtful also in describing

21. Personal discussion of F.R. Allchin with D.K. Chakrabarti, which is mentioned by Chakrabarti in this article 'Reserved Ship Ware in the Harappan Context", in *Puratattva*, No. 8, 1975-76, 159 :

these sherds as 'truly glazed'.[22] Chakrabarti thinks that for these as 'reserved slip wares' *no extra-Indian origin can be traced*. Whatever may be the case, according to Sankalia five stages were required to prepare this type of pottery. These are :[23]

1. Coating of the pot, after modelling with a coloured clay.
2. Burnishing of the coated surface with a blunt instrument.
3. Application of a slip and drying of the pot in the sun.
4. Removal of a part of the slip by a comb-like tool, thus creating a pattern or design.
5. Firing of the pot at a high temperature.

These wares are not frequently found in the Harappan period. The so-called glazed wares were "made of a light gray clay of medium thickness, well-baked and fairly tough. After the application of a purplish black slip probably composed of manganese, a thorough burnishing was done on the

"F.R. Allchin points out that it is not clear from the published description whether the pottery was truly 'glazed' or as seems probable, only with a surface gloss resulting from the fusion of particles of the dressing. There should be a glass surface in a truly glazed pottery and this surface can be achieved through a number of techniques. Accidental fusion of particles of the dressing need not be called a true glaze."

22. In Marshall MIC II, 577-78. Mackay under the heading 'Glazed pottery' has actually described two glossy terracotta (pottery) beads and sherds which look very like copies of Mosaic glass along with the result of chemical analysis of the beads by Hamid. More interesting is the foot-note no. 2 on page 578 of the same volume. "The term 'glaze', here as well as in some other places, is used rather loosely for want of better name for this substance, which though glassy in appearance is not a true glass—ancient glasses being essentially soda-lime silicates."

    In FEM 188, Mackay observes : "This glazed ware is so like mosaic glass that one feels that some craftsman experimenting in this direction perhaps produced a vessel composed entirely of ropy glaze which had fused throughout and could, therefore, not be truly termed as glass."

    Thus it is clear that Mackay was a bit hesitant to accept these sherds as glazed wares. However, if we accept these as glazed wares, the Harappans may be credited as the first users of these sherds in the world.

23. H.D. Sankalia SAPTI 12.

surface. After that a glaze was applied to the surfaces but certainly before firing a portion of both glaze and slip were removed by a comb-like instrument in such a way so as to leave a straight or wavy decorative mark on them.

Black and Red wares are found in the Harappan context mainly at the Saurashtra area. The pottery is black in the interior and red on the surface. H.N. Singh has discussed this ware elaborately in his book *History and Archaeology of Black and Red Ware*.[24] His work is indeed an impressive effort and deserves special mention. It is interesting to note that scholars are not unanimous regarding the technological make-up of the Black and Red Ware. Scholars in India and abroad have advocated divergent theories, which more or less concentrate on the technique of firing. More scientific study and research is likely to throw light on other aspects of this subject, such as the preparation of clay and application of slip etc However, we may at the present state of research accept Singh's[25] comment :

> The technological personality of Black and Red Ware is poignantly diverse for divergent views have been expounded in respect of the technological make up, for example, inverted, single and/or double firing technique of manufacture. There may be still more complex methods of its manufacture which, however, are not firmly tested. This shows a changing technological personality of the Black and Red Ware.

3. TERRACOTTA

Generally baked clay objects are regarded as terracotta and so it is reasonable to connect these with potteries. Terracottas have been found in many perhistoric sites throughout the world and Indian sub-continent is no exception to this. In many prehistoric sites older than those of Harappan we have come across varieties of terracotta in considerable number. The Harappan sites have also yielded the same in great number. The occurrence of a large number of terracotta specimens in Harappan sites is due to the easy availability of alluvial clay —the core material of terracotta—and its plasticity helped a good deal in modelling. A careful study may reveal a techno-

24. H.N. Singh HABRW 1982.
25. *Ibid* 65.

typological continuation of this craft, somehow in a reformed way till now.

The Harappan terracottas include many varieties, such as human and animal figurines, gamesmen and toys and many other models.

The paste of clay used for the modelling of terracotta was virtually the same which was used for making the potteries. This clay burned to a light red colour or dark pink, according to the degree of heat. Probably the source of clay for the potters and terracotta-modellers was the same and it is likely that potters also had some share in modelling other terracotta objects, along with the specialists of this craft. The same 'degraissants', viz., lime and mica have been found mixed with the clay, used for the modelling of other terracotta objects. All the specimens are modelled generally by hand and only a few of them have been found as shaped in mould, viz., the masks and the fine bull. The human figurines, most of which are broken, were made solid. Their physical description is unnecessary for our discussion. These were very simply modelled by hand and some 'appliqué' ornamentation was executed on them. Male figures are rare and female figurines mostly of "Mother Goddesses" are conspicuous in their typical representation. The eyes were represented by pellets of clay, usually oval in shape. The mouth was portrayed by elongated pellets with horizontal incised line to demarcate roughly the lips. The nose was made prominent by simply pinching-up of a portion of the clay.

In modelling of the animals, however, a different method was followed. Mackay's observation on these may usefully be quoted here :[26]

> Unlike the human figures, many of the larger-made animals are hollow inside. Some of them must have been made on a core, but of what material the core was, it is as yet impossible to say, for the inner surfaces of the broken figures are uniformly smooth, though uneven. The core was clearly combustible, since it leaves no trace behind. There are always vent-holes in the unbroken figures, evidently made to permit of the escape of the gases formed in burning the materials of the core. Other figurines were made in a mould. It is easier to press a thin sheet than a thick mass of clay into the crevices of the mould. With the exception of the mask-like faces and the

26. Mackay in Marshall MIC I. 349.

fine bull......which were certainly all made in a mould, the pottery figures of both humans and animals were entirely modelled by hand.

Sometimes the eyes of the animals were represented by a deep incision in the clay and small round pellets were inserted into it to represent the pupil. Sometimes only the pellets were inserted without any incised border line. It is interesting to note that wrinkles in the skin are portrayed by means of incised lines, and heavy folds by the addition of strips of clay to add a 'realistic' touch. In some case the animals stand on a flat pottery base. The animals, represented as models, are dove, peacock, squirrel, mongoose, hare, elephant, monkeys, dogs, pigs, ram, bull, rhinoceros etc.

Sometimes red painting was applied on the models, though the majority of them are devoid of any paint. Better specimens were treated with a cream coloured slip or were washed over with a dark red paint.

Mention should also be made of some terracotta toys like rattles, figures with movable heads, etc. The rattles were roundish in shape with small terracotta pellets inside. These were all made of light red ware. Probably some combustible elements with some already baked pellets were used as the core which was covered with clay and the modelling of the rattle was efficiently done by hand. After firing, the combustible elements were turned into gases leaving the baked pellets inside. We have not found any vent holes for the passing of the gases after the combustion. Probably the gases would pass through the porous fabric of the pottery and to maintain the porosity no slip was probably applied on the rattles. Whatever might have been the case, all the terracotta models were generally well-fired.

The toy animals or human figures with movable heads or hands were separately made and then attached to each other by fastening a string or stiff hair in between.

Like the pottery the terracotta models of the Harappan period betray a sophisticated knowhow. In fact, technical process of the terracotta modelling was not very much different from that of pottery. The basic difference was that the potteries were generally made on wheel while the terracotta models were shaped by hands and sometimes by moulds.

4. TEXTILE

Textile specimen of the Harappan period is extremely scanty due to their perishability. A few specimens which are available were due to their preservation by being impregnated with metallic salts—either of silver or of copper. Instead of conjecturing on what may possibly be found by future excavations we have at present to depend only on what is already found, though this gives us only a very inadequate idea of the textile technology of the Harappan period.

It is almost certain that spinning and weaving were known to the Harappans, as is attested by the discovery of actual woven fabrics, spindle whorls, bobbins, etc.

For spinning of threads, spindle whorls are necessary and considerable numbers of these spindle whorls—chiefly of terracotta and also of expansive faience and shell—are found from almost every Harappan site. Marshall is of the opinion that spinning was a household craft practised both by the well-to-do and the poor alike.

Fragments of cotton textile, dyed red with madder have been found in Mohenjo-daro. Marshall observes :[27]

> The cotton resembles the coarser varieties of present-day Indian cottons, and was produced from a plant closely related to *Gossypium arboreum* or one of its varieties.

This type of cotton was not obtained from any wild species but rather from cultivated plants. However, Mackay has cited the results of the examination of the specimen by James Turner, Director of the Technological Research Laboratory, Bombay. Turner[28] in his preliminary report remarks :

> The fibre was exceedingly tender and broke under very small stresses. However, some preparations were obtained revealing the convoluted structure characteristic of cotton. All the fibres examined were completely penetrated by *fungal hyphae*.... As this examination has been confined to a fragment measuring 0.1 inch in one direction by 0.3 inch in the other direction, these results can only be regarded as tentative.
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> (1) Fibre : cotton.
> (2) Weight of fabric : 2 Oz. per square yard.
> (3) Counts of Warp 34's. Counts of Weft : 34's.

27. Marshall MIC I, 33.
28. *Ibid*, II. 585.

(4) Ends (Warp threads): 20 per inch Pock (Weft threads): 60 per inch.

The results of the examination of other specimens have also been incorporated in Mackay's *Further Excavation at Mohenjo-daro*.[29] The examination of one such specimen on copper razor by A.N. Gulati by means of visual inspection, examination of the fabric with magnifier and a microliner counter, etc. has yielded the following results.[30]

The weave of this fabric was plain, i.e. with an almost equal number of picks and ends per unit length.... The mean of these observations gives 44 picks and 43 ends per inch. The diameter of the yarn varies between 1/50th and 1/80th of an inch....... That the counts of the yarns used in the manufacture of the fabric under examination lie between 13's and 17's. Taking 15's as the average value, the weight of the fabric would be 4 ozs. per square yard. It is therefore to be concluded that the material used in the manufacture of this fabric was cotton.

The use of bast which is highly fragile for weaving has not yet been clearly found from the examined specimes but this was used as string or cord on some metal objects. These were not of convoluted structure and are not properly identified. These were either of jute or flax or of straw or of some wild grass.

Some scholars have suggested that wool was probably used for clothing; but there is no evidence for this so far unearthed.

Probably the Harappans were the first in the world to utilise cotton for manufacturing their clothes and garments.

From no Harappan sites is so far discovered any trace of a loom by which weaving was practised. Probably these were made of perishable materials. Whether these were simple horizontal ground loom or the vertical two-beamed loom or the warp-weighted loom is not known. But textile technology was advanced enough to meet the growing need of consumers. The recovered specimens of textile from Mohenjo-daro are enough to give a fair idea of the development of textile technology in the Harappan period. As the Allchins[31] comment:

That woven textiles were already common in the Indus civilization, and that the craft for which India has remained famous was already

29. Mackay FEM 591-594.
30. *Ibid* 592-93.
31. Allchins BIC 293.

in a mature stage of development, must be inferred from this single find, and from occasional impressions of textiles upon earthen ware, pottery and faience from the Harappan sites.

Therefore, the history of textile technology in India may be traced back to a period approximately 4500 years back. This is one example of how the Harappans surpassed the Sumerians or Egyptians in many respects of technology.

5. TRANSPORT

The invention of the wheel is well-known for its revolutionary consequences. We shall discuss here mainly how it facilitated transport in the Harappan culture.

Growing archaeological evidences, though indirect in nature, throw ample light on the transport technology of the Harappans which they effectively devised to suit both land and water.

We may first discuss the land transport. For inland transport bullock-carts were used—a considerable number of model representations of which in terracotta have been found in many Harappan sites. From these models along with their present equivalents still functioning in the Sind region one can easily reconstruct the actual specimen which was most frequently used.

As Piggott observes[32] :

> For slower and heavier transport, the ox-cart was extensively used in the Harappa culture. Models of carts in clay are among the commonest antiquities on the prehistoric sites of the Punjab and Sind, and the type represented is exactly that which today cracks and groans with its ungreased, nearly solid wheels in the villages round Mohenjo-daro, ... The type, we now know, is unchanged even in its wheel-base, for the recent Harappa excavations have revealed cart-ruts belonging to an early phase of the city's occupations having a width of some 3 feet 6 inches, which is that of the modern carts in Sind. Such things have a long survial-value—the standard gauge of modern English carts was already fixed by the third century B.C., in these islands.

S.R. Rao[33] attempts to reconstruct the models of the carts in more detail :

> Three main types from Lothal are reconstructed with the help of the toy wheels and cart frames found in excavation. The first type has a solid chassis, which is concave or flat. The second and third

32. Piggott 176.
33. S.R. Rao LIC 123.

types have a perforated chassis, but the latter has, in addition, a detachable cross-bar. On such a chassis wooden posts were fixed to form a boxlike frame..... The wheels of Lothal carts were attached to the free projecting ends of the axle which itself was secured with leather straps to the main frame. Lynch-pins seem to have held the wheels in position. The carts with a detachable cross-bar and those with a chassis made up of two curved bars were confined to Saurashtra. Perhaps the latter were meant for carrying light loads, while the other two types carried heavy loads.

In this context Gordon Childe's[34] reconstruction of Harappan cart may also be mentioned :

> In the Indus Valley, numerous models illustrate the under-carriages of the carts of the Harappa civilization, which were constructed in just the same way as the contemporary village carts of Sindh, whose axle turns with the wheels. The frame consisted of two curved beams set parallel, and joined by two to six cross-bars. The pole might run under the cross-bars or be mortised into the foremost. Two or three corresponding holes in each of the side-beams must have held upright poles to contain the box of the vehicle, presumably of wickerwork. A pair of holes at the centre of each side-beam would have held pegs projecting downwards to fit on either side of the axle. Thanks to this arrangement, it is easy to dismantle the vehicle by simply lifting the frame off the axles.

In fact, Childe's reconstruction appears to be more scientific than that of others.

Mention may also be made of another model resembling modern Ekka, the miniature bronze and copper models of which have been found from Harappa, Chanhu-daro etc. This model looks like a little covered trap with a canopy and curtains of fabrics set up on four poles above the cart-frame. In Harappan model is a seated driver, well forward between the shafts and observed as holding the reins with one hand. Gordon Childe also has accepted these as passenger carts. As Childe describes[35] :

> A chassis of the usual type supports a light body covered with a gabled roof. The passengers sit back to back, and in one case the driver sits on the front cross-bar of the frame. Similar vehicles can still be seen in India.

34. Childe in HT Vol. I 717-18.
35. *Ibid* 719.
36. S.R. Rao LIC 123.

Rao[36] conjectures that these were the same as the horse-drawn chariots, described in the *Rgveda,* for which direct evidence at our disposal is at present indeed meagre. Whether spoked wheels were in use or not is a matter of controversy and we have to wait for more evidence.

The long distance journeys through wooded or undulating tracts must have been conducted by caravans of pack-oxen.

For long distance trade and commerce, land transport only was not sufficient and to supplement the land transport an elaborate water-transport network was definitely devised by the Harappans. It was equally or more important than land-transport. In this case also our evidences are not direct, though it is generally admitted that boat and ships were built in this period. Their shapes and technological setup can be reconstructed mainly on the basis of their representations either on seals or on potsherds or even from the terracotta models. S.R. Rao claims that Lothal was a boat building centre too.[37]

From the roughly sketched boat on a potsherd from Mohenjo-daro the following technical characteristics may be discerned[38] :

> It has a sharply upturned prow and stern and is apparently controlled by a single oar. The mast may possibly be a tripod, and one or two yards are shown, or, conceivably, one only, the second line representing a furled sail.

This type was probably river-boats, from which goods were loaded on a shelving bank. On a reused seal the representation of another boat has been found, which is 'mastless with a cabin and a man at oar'. From this representation it is presumed that the real one was probably lashed together at both bow and stern—perhaps an indication of their making of reeds, like primitive Egyptian boats. In the centre there is a hut-like representation, the prototype of a modern cabin, which was also probably made either of wood or of reed. A steersman could sit at a rudder or steering oar on a raised platform over the bow. This was also used probably for riverine traffic. From the terracotta models of boat from Lothal three major types of it are distinguishable ; of these, two types had sails and the other was without sails. In a complete terracotta model of

37. *Ibid* 124.
38. Mackay FEM 183.

boat, according to Rao,[39] a sharp keel, pointed prow and a high flat stern are observed along with three blind holes, one near the stern the other near the prow and the rest near the edge of the boat for fixing the mast, for fastening the ropes of the sails and for supporting the oar respectively. In other models pointed keels, raised sterns and prows are noticeable while in the third type flat base and pointed prow are prominent with the absence of provision for mast.

Rao is of opinion that "the first two types of sharp-keeled boats with provision for the mast must have sailed on high seas, whereas the third type resembling canoes was used in the estuary only."[40] On two potsherds found at Lothal painted depiction of multioared boats have been found, which were most probably used in ancient Sind.

More direct evidences for the anchorage of vessels have also come from Lothal. These are actual stone anchors, circular or triangular in plan with rectangular section and one perforated right across for passing the ropes. "Blind-holes" are also bored on them for anchor-fixing. The identification of these circular and triangular perforated stones as anchors, as is proposed by Rao,[41] is not free from doubt. More scientific and serious investigation may determine their true nature.

The transport technology of the Harappan period, in all probability, has somehow been transmitted to the succeeding period without little change, the traces of which have already been cited by eminent scholars.[42] In comparison to present technology the transport technology of the Harappan period may well be regarded as pre-historic, but in that period it was no less advanced than that of the contemporary Egyptian or Mesopotamian civilization.

39. S.R. Rao LIC 124.
40. *Ibid.*
41. *Ibid* 125.
42. Piggot, (PI. 176) ; Allchins (BIC 272-73) ; Childe (HT, Vol. I. 717-19) ; and Rao (LIC, 123-25), etc. are inclined to draw the analogy of the Harappan bullock carts with the carts in Sind of the 20th century. They also like to see similarity of modern 'ekka' with that of the Harappan models. Rao and Allchins are of the opinion that the present-day country boats and the Arab Dhows have probably some similarities with the Harappan boats.

6. TECHNOLOGY OF SOME STONE OBJECTS

Besides the use of metals like copper and bronze, the Harappans did not give up stone to meet their daily necessities ; rather they had exploited it to the fullest for various purposes. Varieties of objects made of either hard or soft stone were used by them.

Of these we shall discuss mainly the technology of stone blades, boxes, vases, statues and some other minor objects. The technology of stone beads would be discussed separately. Like their ancestors the Harappans were accustomed to the making of stone implements and articles in such a way as to transmit the technology to the Late Harappan Period or even to other chalcolithic peoples after dispersal from their original centres.

The Allchins observe, 'In spite of the commonness of metals, stone was not abandoned, and chert blades were prepared from cores which in turn had probably been exported from such great factories as that at Sukkur (Sakhar)'.[43] Not only this ; the stone blades were imported 'to form a uniform item of equipment at Harappa, Mohenjo-daro, Lothal and Rangpur, Kot-Diji and Kalibangan.'[44]

These blade-flakes of flint|chert were long and parallel-sided, and the technology followed to prepare them was but an inheritance from the preceding periods. Sankalia[45] is of the opinion that this technique was discovered in the upper palaeolithic period. The blade-flakes were long and narrow with more or less parallel edges. These blades were made from a carefully prepared core either by "pressure flaking" technique or by "crested ridge" technique—probably the latter.[46]

In this technique, all the irregularities or whatever could be easily removed from a chalcedony nodule were first removed by a round stone hammer. Secondly, a ridge was prepared along the length of the prepared core by alternate flaking. This ridge is supposed either to guide the regular removal of parallel-edged flakes or it creates a line of weakness which makes it easy for the removal of the first series of flakes.

Such crested ridge flakes and cores still having a ridge on them are found in the Harappan and later chalcolithic cultures.

43. B. & R. Allchin BIC 134.
44. *Ibid*, 268-269.
45. H. D. Sankalia SAPTI 3.
46. *Ibid* 5.

At Mohenjo-daro, flint blades have been found from almost every house. From the discovered specimens the following characteristics have been deduced by the excavators: (i) The flakes were not short; (ii) The form of flint at Mohenjo-daro was a 'brownish-grey chert' which was often mottled; (iii) No trace of patina is observed either on core or on flake.[47] But the observation of Mackay in the second phase of excavation work at Mohenjo-daro is worth adding to this. He says, 'We have in recent years unearthed comparatively few flint flakes or the cores from which they were struck. Those that have been found, whether in the early or later levels, are simple, long, thin, rectangular specimens, trapezoidal in section, with untouched edges and only occasionally with the bulb or percussion at the end. In a great number of cases the bulb seems to have been deliberately removed by snapping it off, with the idea of making the blade as uniform as possible throughout its length... doubtless these ribbon flakes were mostly used as knives.'[48] Mackay is also of the opinion that the flakes were prepared from the 'imported core' and 'no great degree of skill' was required for flaking from the core; only a little practice was enough for the purpose. He also indicates that the possible sources of flint was 'probably the lime stone outcrops at Sukkur' which is supported by the recent observations of the Allchins:[49]

> At Sukkur blades of the type found in Mohenjo-daro and other settlements were also made in large quantities at extensive working areas using the same sources of material as Palaeolithic craftsmen had done earlier. The Harappan craftsmen cleared the earlier materials and flint nodules that had suffered long exposure to the elements, and piled them up in long ridges, or threw them down the sides of convenient hills. They then used the freshly exposed nodules of flint for blade production. The craftsmen appear to have sat cross-legged at chosen spots in the cleared area, and the actual places where they sat could still be recognized when we visited the site in 1976—some four thousand years later! Small kidney-shaped areas were completely cleared of flints down to the residual soil, and concentrations of waste materials, cores and blades could be seen beside them. Studies of the stone industries from settlements of the Mature Indus Period show a distinct and probably rapid development and

47. Mackay in Marshall MIC II. 485.
48. Mackay FEM 395.
49. B. & R. Allchin RCIP 196-97.

convergence from the more varied, individual assemblages recorded at Early Indus and all earlier settlements. The range of artefacts made from blades (in which the local and regional distinctions were seen), drops away almost entirely. What is left is an industry consisting of long, regular blades made from carefully prepared cores of very high quality material obtained from outstandingly good sources of supply. The blade industry of this period is highly professional, and this craft shows an effortless competence, without apparently any desire to produce novel or special results. This is a clear example of the kind of craft specialization that took place at the beginning of the Mature Indus urban period.

A more recent study on the functional aspect of the chipped stone tools has been made by J. M. Kenoyer on the basis of the fresh recovery of the implements from the excavation at Mohenjo-daro by Dales in 1964-65. Jonathan M. Kenoyer has made a careful scientific study of the techno-functional aspect of the tools and his study reveals that stone tools were indispensable, more economical and in some cases more efficient than metal tools.[50]

Bridget Allchin in her 'Substitute Stones' has also thrown some light on the functional aspects along with the technological make-up of some stone objects of Harrapan period. In her concluding paragraph she observes: "the Harappans, far from being a non-violent people, or being without any system of military organization other than that needed to defend their major cities, as has sometimes been suggested, must have had an effective army."[15] Such a conjecture seems to require further confirmation by evidences—direct or circumstantial.

The discovery of a considerable number of saddle querns and muller stones show that argiculturally the Harappans were solvent. These querns with a convex base were crudely made of hard gritty igeneous rock such as basalt and granite and also of sand stone. Three types of querns have been unearthed. On one type a small stone was pushed or rolled and in the other a stone was used as pounder. Eventually there would be a cavity on the second type due to overuse. A rotary quern has also been found from Lothal which is described by Rao:[52]

50. J. M. Kenoyer, "Chipped stone tools from Mohenjo-Daro" in FIC. 117-129.
51. Bridget Allchin, "Substitute Stones" in Possehl HC 237.
52. S. R. Rao LIC. 150.

A unique contribution made by the Lothal craftsmen is the invention of a rotary mill in stone which required less manual labour for grinding corn in large quantities than was the case when a flat pedestalled quern was used. The mill consists of two circular pieces. The upper one has a circular feeding mouth and a square opening below the neck to fix a horizontal stick.

The other querns were probably made by cracking apart a small quarzite boulder and then rubbing together the two new surfaces till they became flat. For stone-rubber a hard white crystalline stone was preferred. The base of the rubber was flat and the upper surface rounded. It was used for preparing the skin. Hammer stones were made by trimming a natural nodule with a pointed tool.[53]

Some palettes of good workmanship are recovered from Harappan sites, which were probably used for rubbing haematite and other colours for cosmetics or for varieties of pigments. These were made from a very dark coloured slate or from dark grey semihard stone. Some stone-built burnishers have also been unearthed from the Harappan sites. These were generally made of chert with a high polish, sometimes bearing oval or triangular section ; these were probably used by the metal workers and potters. The drills, built of hard greyish black stone resembling a fine grained chert were also used by the Harappans for fashioning the interior of the stone bodies. The upper side of the drill was roughly concave and the bottom was convex and the two ends were levelled. It was used by fixing a upright forked stick. Varieties of mace heads—of alabaster, sandstone, cherty limestone etc.—were used, probably as weapons. These were either pear shaped or lentoid and even oval with a conical perforation for fixing a stick. The mace heads were lashed all over probably with raw hides to be firmly secured to a wooden stick.

Harappan sites have also yielded a large number of weights, both large and small with varieties of shapes, which are already discussed by us.

The Harappan stone vessels were generally made of soft stone like alabaster which could only contain dry or oily substances. The technique was not an advanced one—all the products look very rough and clumsy. Perhaps with the help of a tubular drill

53. Mackay FEM 393.

the core was bored. In some cases—specially in the faience vessels—it is found that a specimen was made in three or more separate pieces and then they were cemented together to allow larger cavity in the body ; at the same time narrow neck was provided to prevent the drying of the contents of the jar. Mackay says :[54]

> Most of these tall stone-jars were made on a lathe, though owing to their corroded surfaces it is difficult to prove it ; in shape they are so remarkably regular that it seems the most likely mode of manufacture.....
>
> The interior of each dish was probably hollowed out by means of a specially shaped borer.....The exterior was then probably first roughly shaped and afterwards turned on a lathe, or the dish was laid upside down on a revolving horizontal wheel for the final trimming.

No complex technical method was applied to carve the statuettes, mostly made of soft stones like alabaster, limestone etc. 'Formally and conceptually too, they do not reveal any great imagination or technical skill.'[55] It is also observed by Mackay that 'Other features indicate the very primitive nature of the statuary of Mohenjo-daro, but, none the less, the art of sculpture had so far advanced as to separate some of the limbs from the body'.[56] The heads were crudely carved with the hairs portrayed neatly coiled up in a knot, sometimes hanging in a long plaited knot or even sometimes tied in a fillet. The ridge of the nose was portrayed in a line with the forehead ; the eyes were sometimes inlaid in a refined way. With a thick, short sturdy neck the statues indeed betray no technological mark. However, two statues from Harappa show better technical skill. The Allchins observe : 'no comparable sculptures are known from North India of the early Historic period, and secondly both have drilled sockets to take dowell pins to attach head or limbs, a technique not found in later sculptures.'[57] It is not yet certain whether painting was thoroughly executed on the statue or not. On the trephilo-design of a *shawl* (?) on the famous statue of Mohenjo-daro some

54. *Ibid* 317.
55. Amita Roy, "Harappan Art and Life : Sketch of a Social Analysis" in HS (ed. D. Chattopadhyaya) 177 ff.
56. Mackay in Marshall's MIC I. 362.
57. Allchins RCIP 205.

sort of red pigment is noticed, which suggests the possibility of applying pigment on the statues. The animals were however, carved from a block of stone of which a solid part remained as base.

Thus we see that technology of stone objects, in spite of the profuse use of metals, was not obliterated. In fact the Harappans could not discard centuries of experience due to habit on the one hand and economy and efficiency on the other. When they technically became more habituated to the use of metal they only reduced the stone artefacts but did not abandon it altogether.

7. SEAL CUTTING AND ENGRAVING

Perhaps the most interesting of all objects that have been unearthed at Harappa, Mohenjo-daro, Lothal, Kalibangan, Chanhudaro, Rupar, and many other sites, are the seals, impressed with some kind of undeciphered pictographic writing, theriomorphic, anthropomorphic and therio-anthropomorphic representations. "The number so far discovered in excavation must be around 2000."[58] These types of seals were first noticed by Sir A. Cunningham as is attested by his report on Harappa in the *Archaeological Survey of India : Report for the years* 1872-73 (*pp.* 105-108). Yet even now the Harappan seals are still somewhat of an enigma ; in spite of computer-study recently undertaken for understanding the legends on these we remain far from being exact about what was written on them.

Regarding the functional aspects of these seals, scholars are yet to be unanimous. The theories they propound are but conjectures or a synthesis of various opinions. Roy has aptly remarked : "One cannot be too sure about the social function or purpose of these seals. But it is not unlikely that they served as magical amulets or as sealings of particular religious sects or cults or of economic groups. A deciphering of the writings alone may perhaps provide an answer."[59]

The list of the types of the seals, proposed by Mackay is as follows : (1) cylinder seals ; (2) square seals with perforated boss on reverse ; (3) square seals with no boss and frequently inscribed on both sides, (4) rectangular seals with-

58. *Ibid* 209. But see I. Mahadevan TIC for more exact number.
59. Amita Roy, in HS (ed. D. Chattopadhyaya) 121.

out boss; (5) button-seals with linear designs; (6) rectangular seals with perforated convex back; (7) cube seals, (8) round seals with perforated boss; (9) rectangular seals with perforated boss; (10) round seals with no boss and inscribed on both sides etc.[60]

The seals made for impressing on a soft material like clay and bitumen: These were mostly made of steatite and also of agate, chert, copper, faience and even terracotta. Some of these have triangular or pentagonal or plano-convex section. Mackay discusses in detail the method of manufacturing the Harappan seals, which seems to form the basis of the later discussions of it by Rao and the Allchins.[61]

The seals were first cut into shape and size by means of a saw, which is evident from the saw-marks on the unfinished seals. When the seal was cut into the required size and shape, in most cases a boss was added to it. This boss was at first made roughly by horizontal and vertical cutting on the back. It was then rounded off by a knife and finished with an abrasive. Then a hole was bored through the boss either from the opposite side or horizontally through the bores to take a cord. Generally one third of the area on the back of the seal was covered by a boss. It is likely that before the finishing of the boss the engraving was done; because with a raised projection on the back (i.e. the boss), the seal-cutter would find it a bit difficult to engrave on the opposite surface. According to Mackay '..the device and characters on the seal were cut either before the preliminary shaping of the boss or before it was rounded off and finished'.[62]

The designs were nicely carved by a sharp-pointed burin or by a small chisel. Pointed drills were not used to outline, the figures first; rather it was used only when more details to the carved figures were added. It is interesting to note that the Harappan seal cutters were so skilful that before or without outlining a figure they could start engraving any part of the body with perfection.

Inscription to the seal was added after the carving of the animals or other motifs. According to Mackay, '...the croo-

60. Mackay in Marshall's MIC, II, 370-71.
61. S. R. Rao LIC 95; B. & R. Rllchin BIC 294 and RCIP 201.
62. Mackay in Marshall MIC II, 378.

kedness of some of the characters in the inscriptions suggests that they were added later.... The seal-cutters probably kept a stock of seals by them and added the inscriptions as required.'[63] Could it be that the inscriptions were outlined later by the scribes for the actual seal-cutters to execute on the seals? The inscriptions were generally arranged in a single row at the top of the seal. But sometimes a second row was added and in that case the letters were smaller due to the lack of space.

Next was the task of applying a coating on the seal, which produced a white hue and gloss on the surface. But certainly no colour was applied. Mackay was at first of the opinion that the coating and baking of the seal was done before the engraving of the motifs and inscription. As he put it: 'Possibly, before a seal was considered ready for engraving, it was coated in order to conceal blemishes and then was baked in a kiln.....Besides whitening the surface of a seal, the baking would materially assist in hardening it owing to the loss of water that would result. The process appears to have been carried out before the seals were engraved.'[64] But the fact seems to be that the seals were probaly engraved before the coating and firing. The reasons are not far to seek. If a soft stone like steatite was baked it would have been too hard to be easily and smoothly worked out by the seal-cutters. Secondly,. if the motifs and inscriptions were engraved first and then coated and fired, the edges of the engraved devices would have been more hard and compact than those which were cut after baking the seal. In his later work, Mackay seems to revise his earlier view and observes: 'There is no doubt that after being cut and engraved these seals were treated in some way to produce the white coat that covers them.'[65]

The chemical analysis of the coating on seals was first done by Sanaullah who identified the substance as steatite, saying, 'This surface substance is steatite or talc that has been deprived of the greater parts of its water, which is only possible by ignition.'[66]

63. *Ibid.*
64. *Ibid* 379.
65. Mackay FEM 346.
66. Report of Sanaullah in MIC II. 379.

The chemical analysis is as follows :[67]

	Percent
Silica	61.2
Oxides of aluminium and iron	2.4
Lime	Nil
Magnesia	34.6
Water (by difference)	1.8
Total =	100.00

Mackay adds : 'Mr. Horace Beck after microscopically examining this white coating has come to the conclusion that it is not a slip, but was made by painting the surface with an alkali and then subjecting it to heat. Sometimes this coat shows a certain amount of lamination caused either by the alkali being applied in more than one coat or by the overlapping of brush marks.'[68]

Both Rao and the Allchins agree to the view that the coatings were later applied on the seals. It is, however, unfortunate that chemical analysis of the coating on seals of other Harappan sites has not been incorporated in the excavation reports of the sites.

The Allchins have briefly discussed the method as follows : 'The seals were intaglios, made of steatite, first cut to shape with a saw ; the boss was then shaped with a knife and bored from either end. The carving of the animal motif was done with a burin, probably of copper, and at some stage, generally before carving, the seal was baked to whiten and harden its surface. An alkali was probably applied to the surface before firing to assist in the whitening and to glaze it'.[69] In their later work they have the same thing to say, though with the omission of three words 'The carving of the animal motif was done with a burin, probably of copper, and at some stage the seal was baked to whiten and harden its surface.'[70] The omission of some words—'generally before carving' after

67. *Ibid.*
68. Mackay FEM 346.
69. B. & R. Allchin BIC 294.
70. B. & R. Allchin RCIP 201.

'at some stage' is very interesting. It seems that the Allchins are hesitant to state that the seals were coated and baked before engraving which they proposed in their previous work.

Rao, however, has laid special stress on the Lothal seals. According to him :[71]

> The various stages of producing steatite seals can be followed by a careful study of the seals available from Lothal. In the first instance lumps of steatite were sawn off into tablets with the help of a wire-saw and subsequently chiselled with a stone or bronze chisel. The blocks so produced were reduced to the required size and shape by rubbing on a stone. After cutting the boss on the back, the animal motif was engraved on the face of the seal with the help of a beaked engraver of shell or chert. The pictographic script was subsequently engraved. The perforation of the boss was done by means of two flanged drills of copper driven one each from both sides of the boss. Finally the seal, if made of soapstone, was dipped in an alkali and heated to produce a shining creamy surface and to render the substance harder.

Thus we see that Rao and the Allchins have basically followed Macky in the technological interpretaion of Harappan seals.

8. BEADS

The technological history of sophisticated Indian jewellery and ornaments can be traced back to the Harappan period. The women of the Harappan period were fond of wearing varieties of ornaments, which not only show the technical skill and excellence of the craftsmen but deliberate sophistication of the crafts also. Varieties of innumerable beads, the chief repertoire of the Harappan ornaments were their valued possessions which certainly earned for them not only name and fame but also wealth.

Bead-making is an ancient craft in India. Mackay says: 'There is every probability that in India bead-making was one of the most ancient arts, since in most places the requisite materials were ready to hand.'[72] The Allchins also agree to this.[73]

71. S. R. Rao LIC 95.
72. Mackay in Marshall's MIC II. 510.
73. Allchins BIC 295.

The technique of making beads of semi-precious stones must long have remained a special feature of Indian craftsmanship. Archaeology is able to supply a mass of evidence from sites from the earliest neolithic and chalcolithic settlements in many regions to testify to its longevity. Another, most comprehensive, body of evidence comes from a bead-worker's shop at Ujjain, actually dating from about 200 B.C., which was excavated by N. R. Banerjee. Rao also thinks in the same way when he says : 'It is clear that bead-making has been an important industry during the last four thousand years or more successively at Lothal, Nagra and Cambay—all situated at the head of the Gulf of Cambay. The present day bead-makers follow the same process which the Harappan lapideries had evolved.[74]

On the basis of the above observations we may assert that the Harappans—with some inheritance of their immediate ancestors, whoever they might have been—developed a magnificent technological infrastructure of unprecedented advancement ; some traits of this, though suffering stagnation and conservatism for centuries, had somehow been transmitted to the succeeding cutters of Indian subcontinent, often modified in different set-ups.

However, bead-making was a profitable industry for the Harappans. Rao has aptly remarked that 'the jewellers and bead-makers vied with one another in adorning the person of Harappan women with the choicest product of their trade.'[75] Varieties of beads such as a cylindrical beads, beads of cog-wheel type, fluted tapered beads, long barrel-cylinder beads, barrel shaped beads, long barrel beads, short barrel beads, disc shaped beads, globular beads, segmented beads, pottery beads, etched carnelian beads, composite beads, immitation etched carnelian beads, wafer-beads, tubular denticular beads etc. are found from Harappan sites.

The materials used for making beads also varied. These were steatite, faience, a hard viterious paste (allied to faience), pottery, shell, agate, carnelian, jade, quartz, limestone, jasper, lapis lazuli, green felspar or amazonite, onyx, gold, silver,

74. S. R. Rao LIC 103.
75. *Ibid.* 102.

copper or bronze etc. This shows that the Harappans were very keen in selecting the materials for making beads. At the same time they must have been quite familiar with the fibres of the stones which were not always locally available and hence imported from the far off places. The Harappans imported the raw materials and exported the finished goods and thus technology went hand in hand with production, consumption and export.

Mackay has done a comprehensive study on the process of bead making in ancient Sindh on the basis of his discovery at Chanhu-daro. Rao has also done the same on the basis of his discovery at Lothal in Gujrat. Wheeler, the Allchins etc. have basically followed the line of Mackay. According to Wheeler:[76]

> The Harappan beads are abundant, varied in form and material, and important historically.....The processes of sawing, flaking, grinding and boring the stone beads are well illustrated at Chanhu-daro, where a bead-maker's shop was found. The technique was a laborious and skilful one. The stone (agate or carnelian) was first sawn into an oblong bar, then flaked into a cylinder and polished, and finally bored either with chert drills or with bronze tubular drills. Alternatively, almost incredibly minute beads of steatite paste seem to have been formed by pressing the paste through fine gauge bronze tubes. The stone drills were very carefully made with tiny cupped points to hold the abrasive and water that gave the drill the necessary bite.... No site has produced so many of them as Chanhu-daro, and the possibility of an export-trade in beads from the Indus is worthy of consideration.

We shall discuss here the observations of Mackay. According to him the nodules of stones were at first split along the longer axis to produce some roughly made square or rectangular slips or rods but the easier method was to cut the rods or slips longitudinally from the core nodules by a saw together with fine abrasive. This saw was probably a toothless metal one. Rao[77] is of opinion that before the preparation of the rods or slips the stone was cooked in small earthen bowls. Then the coarse stone was split by giving heavy blow and it was thus reduced to the required size. However, later on, by careful minute flaking uneven angular surfaces were removed to make the slips or rods somewhat round. Then the round

76. Wheeler IC 98.
77. S. R. Rao LIC 103.

shaped rods or slips were ground and rubbed on a sand stone. For the barrel shaped beads one half of the bead was first rubbed and then the other half. The ends were also ground to flat. One of the most crucial parts of bead making was the boring of holes. Each end of the bead was roughened so that the drill could not slip at the time of boring. This boring of the holes was done by stone drills. Mackay says :[78]

> That stone and not metal drills were used in boring the hard stone beads of Chanhu-daro is now proved by a large number of stone drills being found there....The business end of these stone drills is rounded, with a slight depression in the centre. A micro-photograph of the end of one (greatest diameter 0.12 in.) clearly shows the concentric markings formed by an abrasive in its rotation against a hard substance, or, alternatively, the rotation of a hard stone against it. All these drills, whether black or dark brown in color, were made by roughly flaking the stone into a rod-like shape, and then grinding them in much the same way as the beads. They are never of the same diameter right through, but narrow slightly just above the working end and then thicken towards the butt, which more often than not has slightly faceted sides, doubtless to prevent its turning in the handle or chuck in which it was fixed. It might not at first appear possible to use so brittle a drill with the hardness of 7 against a material of similar hardness, such as agate or carnelian. By itself the drill would have made little or no impression on these stones, but the use of a fine abrasive with it, such as emery or crushed quartz, would entirely alter matters. C. H. Desch, Director of the National Physical Laboratory,.....to whom I submitted some of these drills for experiment writes as follows : 'I think that the depression at the end of the drills is intended to hold the abrasive under the drill and prevent it from escaping. I mounted one of the stone drills in a small Archimedean brace, which I held vertically. The action would be just the same as that of a bow drill. Using 120-mesh emery and water, I found that it took about 20 minutes to drill a depth of a millimetre in one of the rough pieces of carnelian. A small depression must have been made to locate the drill, as on a flat surface the drill wanders around before getting to work. The drilling is certainly quite practicable. Failing emery, possibly even sand may have been used. The wear on the drill is very slight.

But Rao comments : 'Drilling was done by the Harappans by means of two flanged drills of bronze placed pointed towards the centre at either end of the bead. Chert drills do

78. Mackay in JAOS, 1937, 6-7.

not appear to have been used for this purpose as suggested by Mackay.'[79]

Accepting the views of both Rao and Mackay, it may be noted that the Harappans used both stone and metal drills at two bead making centres viz., Chanhu-daro and Lothal. However, a bow was probably used to hold the stone drill at the time of working. Pump-drill might also have been used. Every hard stone bead was bored from both flat ends and thus the drill holes met approximately in the middle. Due to the use of fine abrasive the bore holes look very polished. In the Cambay region boring was done at last, whereas in the Sindh region boring was done before the final finishing. Then a fine polish was executed on the beads but the means are not yet clearly known. Rao says: 'Finally, the bead was heated once again to get the necessary glow...'[80] But Mackay does not mention it.

This, in brief, is the general process of making beads in the Harappan period. But mention should also be made of some special types of beads for which technical skill, patience and painstaking labour were certainly needed. One of these types was microsteatite beads. These beads were so minute that their boring was a real problem on the part of the bead-makers. Let us quote Mackay on this point:[81]

> Mr. Horace Beck, to whom I have submitted samples, writes as follows: 'The smallest bead which I have measured from Chanhu-daro is 0.0268 in. in diameter, which means 37.3 to an inch. It is stated that some specimens from the Harappa site are as small as 0.021 in., but the smallest that I have measured was 0.025 in. The perforation of the Chanhu-daro beads is approximately 0.01 in. An average of the perforations of the six beads measured was 0.0098, the maximum being 0.0107, the minimum 0.0083. After carefully examining a modern watch maker's drill which is capable of drilling holes 0.01 in. (0.25 mm.) in diameter, it is difficult to believe that either the drill or the bead could have been held by the hand, so I suggest that some form of lathe or jig must have been used'....
>
> Every one of this type of bead was bored, and, as the illustration shows, they had once been strung together. How such minute beads could be bored puzzles Mr. Beck and myself.

79. S. R. Rao LIC 103.
80. *Ibid.*
81. Mackay in JAOS 1937. 10-11.

To this Mackay adds :[82]

The beads were in fact made as long tubes, and the spiral furrowing...suggests that these tubes were shaped by squeezing a composition through an aperture; though how tubes rather than solid rods were produced it is difficult to see. Where two beads were found almost united and with their markings continuous, it seems that they must have passed after one another through the same apparatus.... At any rate these beads show craftsmanship of the highest order combined with extraordinarily good eyesight.

Mackay's observation appears to be convincing when he says that these were at first produced by extrusion process as a uniformed tube from an aperture. But about the type of aperture from which the tube was extruded, Mackay is somewhat silent. However, a great deal of information has been supplied to us by K. T. M. Hegde and others. They have put forward a convincing hypothesis of the material and technology of Harappan micro-beads after the recovery of such beads at Zekda. According to them these beads were not made from pure talc (4 Mg O5 SiO_2 H_2O) which is a hydrated silicate of magnesium and the presence of alumina indicates the presence of Kaolinite (Al_2 $O_3$2 SiO_2 $2H_2O$) in the composition of the original material and the Harappans deliberately mixed talc and Kaolinite in the ratio of five to one. But the natural formation of this material is also found as talcose steatite which may also have been used by the bead-makers of Harappan pe·.od.[83]

On the technology of these beads Hegde and others conclude :[84]

We therefore suggest, keeping in view the known Harappan technological infrastructure, the following simple process as a plausible method for the manufacture of these micro-beads. All that is needed is a circular copper or bronze disc with a few one millimeter diameter perforations near the centre. Each perforation must have a copper or bronze wire of 0.5 millimeter diameter with one end soldered or riveted near the perforation and the other end bent and positioned to be at the center of the perforation... The disc has fine holes at its periphery which allow it to be stitched all around to a well-knit piece of cloth. If into this device a paste of finely ground talcose

82. *Ibid* 12.
83. K. T. M. Hegde *et al* in Possehl HC 241.
84. *Ibid* 242-43.

steatite is put and the cloth gathered together and squeezed by hand, talcose steatite paste emerges through the perforations as tubes. These soft tubes can be cut as they emerge, at quick intervals, to convert them into microbeads.

Three skillful persons are necesary to do the job : one for squeezing the paste, the second for cutting the soft tubes and the third for collecting the soft microbeads, over a layer of fine ash on a dish, to avoid damaging them. The beads can then be baked at 900 to 1000° C in a kiln to harden them. We have adequate evidence to believe that Harappans had the necessary infrastructure to attempt such a process.

They had copper and bronze discs. There is even evidence of perforated examples. They knew both soldering and rivetting. They sometimes soldered the rivet by pouring molten copper or bronze around its base for additional firmness (Marshall 1931 : 489). They had cloth (Marshall 1931 : 585-86). The soft tubes appear to have been cut by a thin, sharp device to convert them into microbeads. A simple device to serve this purpose is a horse hair. Harappans had horses (Marshall 1931 : 653-54; Joshi 1972 : 135). The fact that they could melt copper at 1080°C, clearly shows that they had suitable kilns or open fires with a forced draught to raise the temperature of the fire to 1200°C so as to bake the beads at 1000°C.

It appears probably therefore, that the Harappans microbead makers produced these beautiful, tiny beads by means of simple process. But it was, nevertheless, a laborious, painstaking, unhurried job.

Larger steatite wafer beads were[85] at first shaped as a long rod and subsequently cut up into segments with the aid of a saw. The perforation of these beads were done by a fine metal point. But we have come across small wafer beads also, Probably these were made by means of cutting up steatite into thin plates and were rubbed down to required thinness. Then these plates were cut into blanks approximately to the size required for the bead. Then these were rounded off, perforated and heated at 900°C for hardening.

Another type of beads are the carnelian beads which were in all probability exported by the Harappans.[86] Whether they were the first discoverers of these beads is yet a question not fully answered.

85. Mackay in JAOS Vol. 57, 1937. 12.
86. *Ibid* 14.

On the basis of the detailed review of Dikshit, Sankalia has described three techniques of manufacturing etched carnelian beads :[87]

Technically, there are three types of etched beads.

Type I : White patterns on red background.

Type II : Black patterns on whitened surface of the stone.

Type III : Black patterns etched directly on the stone.

Beads of type I are most common ; of type II rare, and that of type III almost negligible, still all of them go back to the Indus or the Harappan Period, and thus the techniques should have been in existence by at least 2300 B.C.

Technique :

1. The white patterns on the red surface were prepared by making a thick liquid of potash, white lead, and the juice of *Kiral bush* (*Copparis aphylla*). This was then applied directly with a pen on the carnelian. Heated on a charcoal fire the design became permanent.

Microscopic analysis of these beads showed that the etching produced a number of minute spots, under different coefficients of expansion. The white layers do not affect the extreme surface of the stone.

2. In type II beads, the white surface is first prepared with alkali. On these are drawn lines in black, prepared from metals like copper and manganese. The effect is sometimes purplish.

3. In type III, a pattern in black is etched directly on the original surface of the bead.

It is also further noted that the three techniques do not always appear exclusively. Combinations of Types I & II (Variety A) and of types I and III (Variety B) are at times noticed.

From the above one is tempted to think that the Harappans had some understanding of chemistry, though it remains for us to see whether chemistry as a "conscious" natural science could emerge among them.

87. H. D. Sankalia SAPTI 40-41.

TABLE I

(Tables of Chemical Analyses)

Chemical analyses of Ceramic materials found at Mohenjo-daro

(After Marshall, 1931, Vol. II. p. 689)

Specimen	Silica	Alumina	Ferric Oxide	Ferrous Oxide	Manganese Oxide	Lime	Magnesia	Alkalies	Copper Oxide	Water	Analyst
1. Black bangle	54.28	19.63	—	8.70	0.13	9.63	4.39	3.43	—	—	Mohd. Sana Ullah
2. Greenish pottery	52.39	17.03	5.30	2.29	—	15.78	4.45	1.71	—	1.05	do
3. Faience Vase (bluish-green)	89.76	3.86	0.93	—	—	0.88	tr.	4.07	0.50	—	do
4. Faience bangle (bluish-green)	88.12	3.02	1.82	—	—	1.26	—	—	0.46	—	do
5. Faience tubular bead (chocolate)	91.07	2.44	1.15	—	tr.	1.28	tr.	2.08	Cu 20 1.98	—	do
6. Steatite disc.	57.99	4.85	—	—	—	4.31	27.20	3.54	1.09	2.01	M A. Hamid
7. Faience Statuette	57.23	3.69	—	—	—	6.39	28.99	1.88	0.46	1.36	do
8. Slip from steatite Seal	61.2	2.4	—	—	—	—	34.6	—	—	1.8	Sana Ullah
9. Steatite flat beads	63 65		—	—	—	—	31.80	—	—	1 09	do

TABLE—2

(Analyses of the glazed Ware)

(After Marshall, 1931, Vol. II, p. 578)

Analyst. Dr. M. A. Hamid

Pottery base of bead.	Per cent.	The White glaze.*	Per cent.
Silica	71.12	Silica	86.28
Alumina	9.27	Alumina and Iron oxide	7.78
Iron oxide	10.91	Lime	2.35
Lime	1.77	Magnesia	0.61
Magnesia	1.55	Soda	1.21
Soda and Potash	3.77	Potash	Nil
Loss on ignition	1.69	Loss of ignition	2.05
Total	100.08	Total	100.28

*The term "glaze," here as well as in some other places, is used rather loosely for want of a better name for this substance, which though glassy in apperance is not a true glass—ancient glasses being essentially soda-lime silicates.

CORRECTIONS TO TABLES I & III

Table I

Copper Oxide in Column 5 : Cu_2O, 1.98
Alumina in Col. 6 : 4
Ferric Oxide in Col. 6 : 0.85
Alumina in Col. 7 : 3
Ferric Oxide in Col. 7 : 0.69
Alumina in Col. 8 : 2
Ferric Oxide in Col. 8 : 0.4
Alkalies in Col. 4 : Na_2O, 4.50 ; K_2O, 0.65
Magnesia in Col. 9 : 33.80

Table III

Magnesium Carbonate to be transferred under the heading "Carbonate of Lime"
SK Site to be read as DK Site

TABLE III

Mortars (After Marshall, Vol. II / p. 689)

Locality	Gypsum	Carbonate of lime	Sand	Alkaline Salt	Moisture	Analyst
Wall (HR Site)	74.12	2.50	20.41	1.18	1.79	Mohd. Sana Ullah
do	63.25	0.66	31.61	3.47	1.01	do
Tank (SD Site)	43.75	13.78	38.04	2.47	1.96	do
Drain (DM Site)	56.73	24.87	16.64	—	1.76	do
Vat (HR Site)	Nil	69.58	21.71	5.44	3.27	M. A. Hamid
Drain and Cesspit (SK Site)	Nil	39.96	46.74	0.74	3.74	Mohd. Sana Ullah
Magnesium Carbonate	Nil	8.82	Nil	Nil	Nil	Nil

2. Nodules of gypsum mortar analysed by H. P. Plenderleith (after Mackay, FEM, p. 598)

Moisture	3.60%
Water (Combined)	0.01%
Silica	23.05%
Iron oxide and alumina	3.43%
Calcium sulphate	55.67%
Carbonates	Nil
Magnesia and alkalies	not estimated :—

"Lime mortar (Mackay, FEM, p. 598).

Calciumcarbonate	39.96%
Magnesium carbonate	8.82%
Gypsum	traces.
Water	3.58%
Sand, clay, etc	47.64%

TABLE—4

(After Marshall Vol. II pp. 689-690)

A black coal-like substance found at Mohenjo-daro has been identified by the writer as *Silajit* or *Shilajatu*, an ancient Indian Medicine. It occurs as an exudation on rocks in the Himalayas, and is popular with the physicians following the old school....The composition of Mohenjo-daro specimen (M) is shown against those of four specimens analysed by Hooper (JASB.72 (1903), 98-103) in the table below :

Analysis of Silajit

	M	I	II	III	IV
Water	15.99	9.85	15.90	11.15	10.99
Organic Matter	55.24	55.20	49.86	51.55	56.86
Ash	28.77	34.95	34.24	37.30	32.15
	100.00	**100.00**	**100.00**	**100.00**	**100.00**
Ash :—					
Silica	8.23	1.35	1.62	18.10	10.15
Alumina	2.43	2.24	1.08	6.00	4.64
Ferric Oxide	1.44				
Lime	7.31	4.36	3.96	3.86	3.88
Magnesia	0.32	1.50	0.52	0.15	1.34
Alkalies	9.04	13.18	14.32	4.78	6.91
Carbonic acid, etc.	Not determined	11.51	12.13	3.69	4.83

(Analysis of M. by Dr. Hamid)

TABLE—5

Lollingite

(After Marshall, Vol. II, p. 690)

"Specimens of lollingite or leucopyrite also deserve special mention as they bear evidence of having undergone ignition. Under the action of strong heat, these minerals give off arsenic; or its white oxide, when roasted in air. It is, therefore, highly probable that these minerals were employed for making arsenious preparations, either for medicinal purposes or for destroying life...The composition of a natural lollingite specimen (B) is given in the table below along with those from Indus Valley sites."

Analysis of Lollingite

	B.	I.	II.	III.	IV.	V
Iron	27.14	54.55	49.3	45.63	51.7	48.1
Arsenic	72.17	34.02	43.6	47.12	43.9	48.6
Copper	—	0.92	0.7	—	—	—
Sulpher	0.37	1.38	0.16	—	—	—
Water	—	7.68	4.7	—	—	—
Insol	—	1.45	0.8	—	—	1.9
Sp. gr.	—	4.0	5.6	—	—	—

(Analysis of the natural specimen (B) is by Brevik and those of the Indus specimens by the writer).